SMALL-SIZE EXPLOSIVE GAS MEASURING SENSOR MIPEX-03-X-XX-X.X

USER MANUAL

ESAT.413347.006 UM

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Table of Contents

INTRODUCTION 3

1. DESCRIPTION 4

2. TECHNICAL SPECIFICATIONS 5

3. INTRINSICALLY SAFETY 6

4. PRECAUTIONS 7

5. INSTALLATION AND SERVICES 8

6. DESCRIPTION OF ANALOG OUTPUT 11

7. STORAGE AND TRANSPORTATION 14

8. WARRANTY 15

9. CONTACTS 16

Appendix A. Sensor types and characteristics. 17

Appendix B. Connection diagram. 22

Appendix C. UART communication protocol. 24

Appendix D. Sensor zeroing and calibration. 29

Appendix E. Attaching the dust filter. 32

List of abbreviations:

CGM – Control Gas Mixture;
EMI - Electromagnetic Interference;
LEL – Lower Explosive Limit;
MCU – Microcontroller Unit;
NDIR - Non-Dispersive Infra-Red;
UART - Universal Asynchronous Receiver/Transmitter.

INTRODUCTION

MIPEX-03-X-XX-X.X (hereinafter, sensor or MIPEX-03) is the gas sensor, which is intended for automatic continuous measurement of concentration of hydrocarbons in explosive areas and carbon dioxide.

Sensor can be used as part of gas-analyzing equipment of groups I and II according to IEC 60079-0 in the explosion-hazardous zones of classes 0, 1, 2 according to IEC 60079-10-1, and Class I, Division 1 according to UL913, CAN/CSA-C22.2 No. 157-92.

Optosense LLC reserves the right to update and change current UM in parts exclude intrinsic safety parameters and accompanied information specified below.

1. DESCRIPTION

The principle of sensor operation is based on NDIR technology.

The infrared radiation of a light-emitting diode permeates a measuring diffusion-type gas cell and gets at 2 light-sensitive cells; one of them is responsive to radiation in the range of wavelength of 3.25 to 3.45 μm only, while the other one registers radiation in the range of wavelength of 3.1 to 3.25 and 3.45 to 3.7 μm. The investigated gas present in the cell absorbs radiation of the operating wavelength (λo) and does not affect radiation of the reference operating wavelength (λr). The amplitude Io of the light-sensitive cell operating signal changes upon changing concentration in accordance with equation:

$$Io/Ir = \exp\{-[K(\lambda o) - K(\lambda r)]CL\}; \quad (1)$$

where:

K (λ) – coefficient of absorption at a given wavelength;

L – optical length of cell;

C – measured concentration of gas;

Io, Ir – amplitude of signals at light-sensitive cell.

The concentration of gas is:

$$C = -Ln(Io/Ir)/(L[K(\lambda o) - K(\lambda r)]); \quad (2)$$

Using differential dual wavelength method of registration allows eliminating influence of water vapor, contamination of optical elements and other non-selective hindrances affecting both channels similarly.

The sensor structure contains an optical cell with a mirror system, infrared light-emitting diode (LED), LED driver, receivers of Signal and Reference channels, analog amplifiers, microcontroller and supply voltages unit.

The microcontroller of the sensor performs:

- storage of unique calibration constants;
- calculation of gas concentration based on measured results;
- communication though UART and analog output interface.

The sensor is enabled on power is up and disabled on power is down.

2. TECHNICAL SPECIFICATIONS

Table 1. Technical specification.

General	**Gas sampling method:**		Diffusion
	Operating principle:		Non-Dispersive Infra-Red (NDIR)
	Target gas *		CH_4
			CH_4 /CH_4 +C_2H_6
			C_3H_8
			$C0_2$
	Operating, storage and transportation conditions:	**Relative humidity**	up to 98%
		Atmospheric pressure	80-120 kPa
		Temperature range	-40... +60 °C
	Overall dimensions *		ø20x16.5 mm without pins
			ø22x16.5 mm without pins
	Pins length		4,6
	Weight *		16,6 g
			15,5 g
			5,5 g
	Enclosure *		Stainless steel (standard and fast response versions)
			Plastic
	MTBF		10 years
Measurement	**Measurement range ***		100% Vol
			5% Vol
			2.5% Vol
			100% LEL
			1.5% Vol
			ALARM SENSOR
			50% LEL
	Accuracy *		±0.1 % Vol or ±5 % of indication
			±3 % LEL or ±5% of indication
	Response time, T90 *		10s
			20s
			30s
			60s
	Temperature, pressure and humidity performance		According to Appendix A.
Electrical	**Supply Voltage Range:**		3.0 – 5.0 VDC
	Output signal *:		digital UART, analog output
	Power consumption:		<5mW
	Warm-up time:		not more than 1 min
	Degree of personal protection against electrical shock caused by the sensor		meet the requirement of class III GOST 12.2.007.0
Marking and standards compliance			**Ex ia I Ma/Ex ia IIC Ga.** acc. to IEC60079-0, IEC60079-11, IEC60079-26. -40^0 ≤ Ta ≤ +60 ^{0}C
			IM1/II1G Ex ia I Ma / Ex ia IIC Ga. acc. to EN60079-0, EN60079-11, EN60079-26. -40^0 ≤ Ta ≤ +60 ^{0}C
			RECOGNIZED COMPONENT Intertek 4004454 **Class I,Division 1,Group A,B,C,D** CONFORMS TO UL913,60079-0,60079-11Std. CERT. TO CAN/CSA-C22.2 No. 157-92 Std.

* Available options. See Appendix A for details.

3. INTRINSICALLY SAFETY

Combined intrinsically safe parameters of sensors circuits are as follows:

IECEx/ATEX: Ui = 5.0V, Ii = 200mA, Pi = 0.13W, Ci = 5.95µF, Li = 0.

CAN/CSA: Vmax = 5.0V, Imax = 200mA, Pmax = 0.13W, Ci = 5.95µF, Li = 0.

It is allowed to connect the sensor only to intrinsically safe circuits with the rated direct current output voltage (U0) within the range of not less than 3 V and not more than 5 V, with the output power (P0) - not less than 0.02 W and not more than 0.25 W.

The gas-analyzing equipment, which is used with MIPEX-03, must meet the requirements of IEC60079–0, IEC60079–11, IEC 60079-14 and have parameters conforming the MIPEX-03 intrinsically safe pointed above.

4. PRECAUTIONS

- Inspection and maintenance of the sensor shall be carried out by suitably trained personnel in accordance with the applicable code of practice (e.g. EN 60079-17).
- The persons who have studied this UM, have been briefed on safety precautions when operating electrical equipment intended for operation in the explosion-hazardous zones in the established order, are admitted to operate the sensor.
- Repair of the sensor shall be carried out only by personal of manufacturer or authorized by manufacturer.
- It is interdict to discharge the control gas mixture (CGM) to the atmosphere during sensor calibration.
- Do not allow the contact of sensor with aggressive substances e.g. acidic liquids or gases that may attack metals, or solvents that may affect polymeric materials.

5. INSTALLATION AND SERVICES

- MIPEX-03-X-XX-3.X POTENTIAL ELECTROSTATIC CHARGING HAZARD – CLEAN ONLY WITH A DAMP CLOTH. The external part of the sensor can be sourced of risk of electrostatic discharge. Take it into account during installation and operation of the sensor in end-user equipment.
- The MIPEX-03-X-XX-1.X and MIPEX-03-X-XX-2.X models of the equipment were tested and found to hold 18.3pF maximum capacitance.
- Connection should be made via PCB sockets. Soldering to the pins will seriously damage the sensor.
- Excessive force on sensor housing is not allowed: no more than 2 MPa applied to reflecting cover center or on at any point of middle part side surface and no more 200 MPa applied to boundary of reflecting cover.
- Metrological properties are not supported in ambient temperature gradient faster than 0.6 ^{0} C/min.

5.1 Preparation

5.1.1 If the sensor has been kept in the transportation package at temperature lower than 0^{0}C, hold it at temperature of 10–35 ^{0}C for at least one hour.

5.1.2 Remove the packing. Check presence of the certification marking, ensure absence of mechanical injuries.

5.2 Installation

Use intrinsic safety connection given in Appendix B.

5.2.1 Use recommended sockets **Cambion 450-3326-01-06-00** for the sensor connection or similar. Sensor pinout is shown in Appendix A.

5.2.2 Provide power supply of the sensor from power sources featuring nominal range of output DC voltage of not less than 3 V and not more than 5 V, output power (P0) – not less than 0.02 W and not more than 0.25 W in accordance with requirements of standards IEC 60079–0:2004, IEC 60079–11:2006. For all MIPEX-03 modification polarity of power supply does not matter.

5.2.3 The transceiver of serial interface UART for MIPEX-03-X-XX-X.2 and MIPEX-03-X-XX-X.3 should meet the requirements of standards IEC 60079–0, IEC 60079–11.

Communication parameters of UART-transceiver are following:

- HIGH logic level for TxD line of sensor is 2.8V;

- HIGH logic level for RxD should be at range of 2.8V…3,3 V;

- LOW logic level 0 V;

- Maximum output current of UART not more than 25 mA.

5.2.4 Analog output (AnOut) for MIPEX-03-X-XX-X.1 and MIPEX-03-X-XX-X.2 should be connected to R load. Recommended R load is 10kOhm. Maximum output current of AnOut is 10 mA.

- MIPEX-03 has pulsed power consumption. Maximum current may shortly rise up to 10 mA during 10ms pulse length. Average consumption is less than 1 mA (see Fig. 1 and Fig. 2).
- In case of the sensor sends the commands via UART maximum current consumption may rise up to 10 mA during 60 ms.
- After power up, during 60s warm-up time, the sensor does not return the concentration value (the value displays as “-1”). After that sensor starts to transfer measured values.
- After warm-up (1 minute after power-up) the sensor makes self-diagnostic test during 2 minutes.
- Please note, if the dust filter from sensor’s kit was attached, then ZERO2 command must be send after Warm-up time.
- Sensor updates information about concentration every approx. 1.3 sec. Sending command more often than 1 time per sec (1 Hz sampling rate) is not recommended, otherwise the temperature sensor accuracy comes down.

5.3 Proper use

The sensor outputs information about measured concentration value though the digital serial interface UART or analog output (see chapter 6 for details). Data communication protocol is given in Appendix C. Methods of setting zero of the sensor and re-calibration are given in Appendix D.

The sensor is designed for continuous operation.

There is self-testing algorithm inside the firmware code.

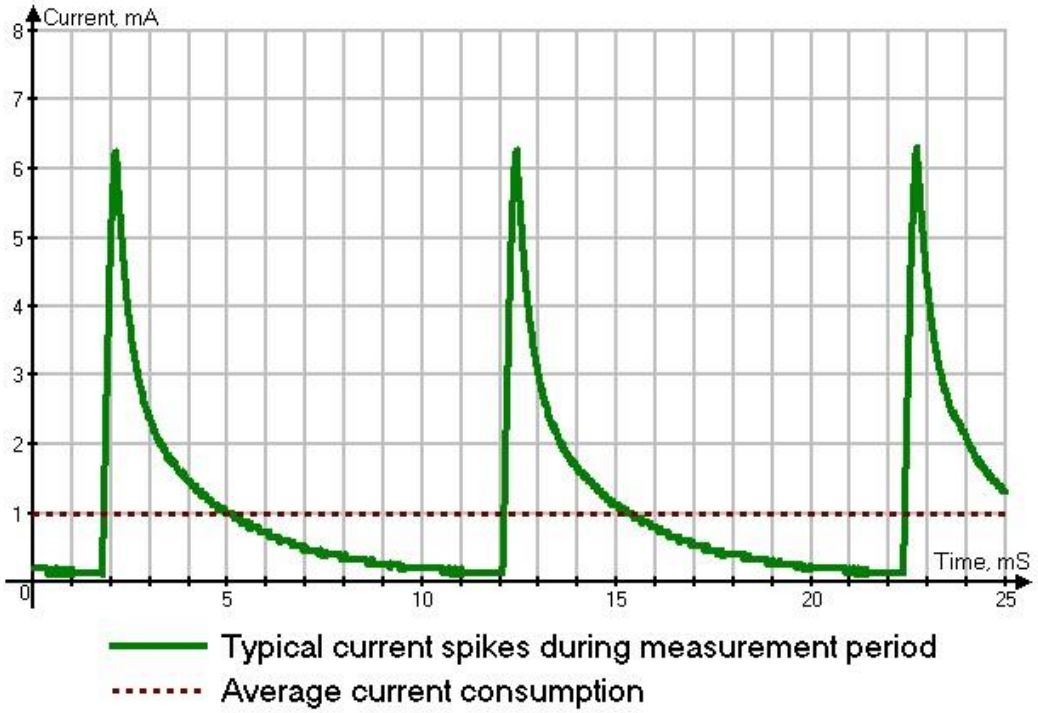

Fig. 1. Typical current consumption waveform vs. time (R=30 Ohm, C=20 uF)

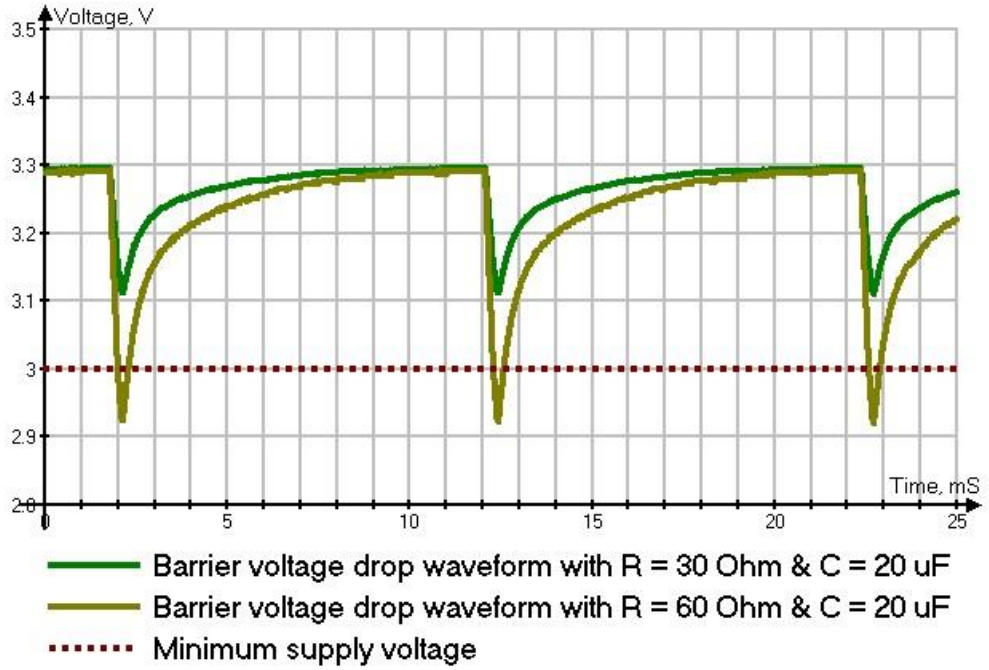

Fig. 2. Typical barrier voltage output vs. time (3.3V input)

6. DESCRIPTION OF ANALOG OUTPUT

Preset of analog output (AnOut) must be additionally noted within purchase order. For MIPEX-03-X-XX-X.1 and MIPEX-03-X-XX-X.2 models the range of output voltage can be configured through UART. Henceforth, the range of output voltage might be reconfigured by user. For MIPEX-03-X-XX-X.1 (3 pin model) this operation will require MIPEX-03 special contacting device and configuration unit (acquire separately).

AnOut UART configuration procedure:

6.1 Setting up the output mode

The command **DACMODE** is used to set analog output mode. There are four possible modes of analog output:

- **DACMODE0** - switch off analog output. Digital interface is used if available;
- **DACMODE1** – initiate the mode, where 0.4V output is relative to zero gas concentration and 2.0V is a maximum;
- **DACMODE2** - initiate the mode, where half of input voltage is relative to zero gas concentration and maximum concentration relative to maximum output voltage (pellistor replacement POSITIVE adaptation).
- **DACMODE3** - initiate the mode, where half of input voltage is relative to zero gas concentration and maximum concentration relative to minimum output voltage (pellistor replacement NEGATIVE adaptation).

Depends on sensor polarity in user device the commands **DACMODE2 / DACMODE3** could work in converse modes.

Default setting of a Digital-Analog Converter (DAC) is 0.4…2.0V. Using analog output in **DACMODE1** mode is possible to adjust DAC range using command **SETDAC1 XXXXX (**to set MIN output) and **SETDAC2 XXXXX (**to set for MAX output) where **XXXXX** is DAC readings in range 0… 04095. To request current DAC settings send **SETDAC?**. The response is relative to MIN and MAX output.

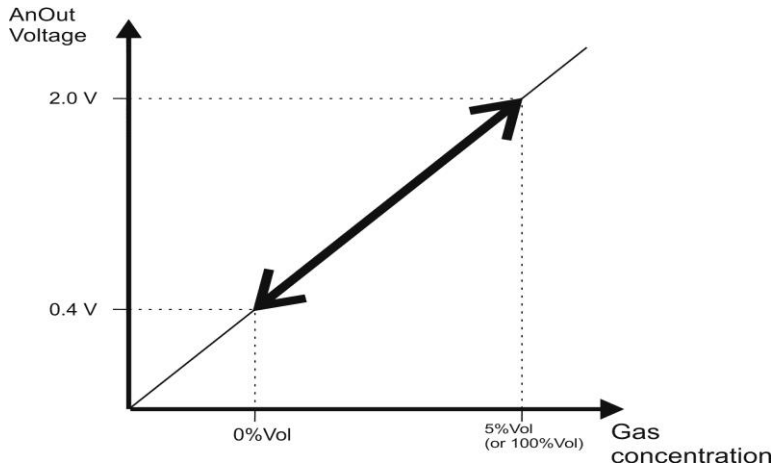

Fig. 3. U_{AnOut}(C) for **DACMODE1**.

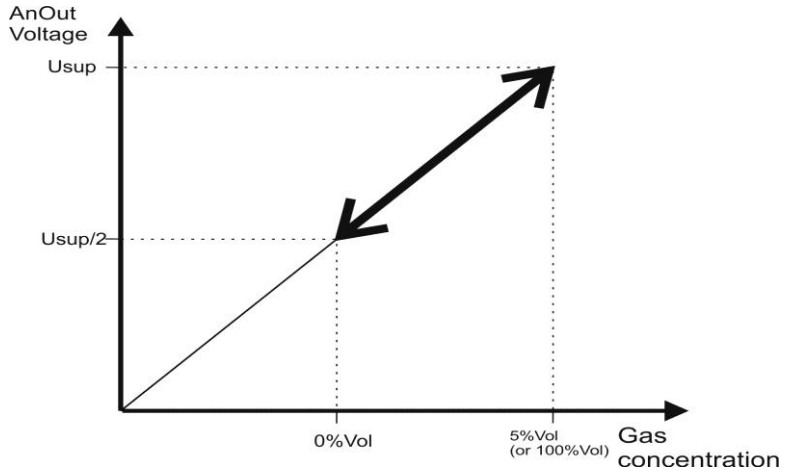

Fig. 4. $U_{AnOut}(C)$ for **DACMODE2**.

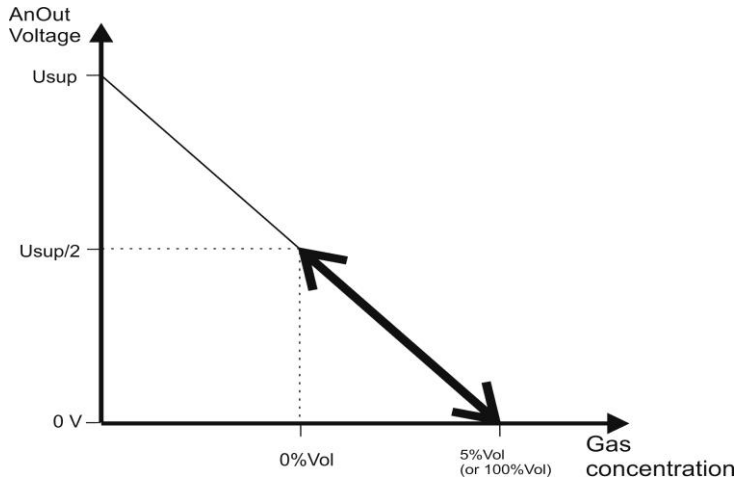

Fig. 5. $U_{AnOut}(C)$ for **DACMODE3.**

6.2 Setting up the output range.

ALMH XXXX is ASCII command to setting up the concentration value **XXXX** (in %Vol*100) for upper voltage output level for any **DACMODE**.

For example, to set up measuring range 0-5%Vol of CH4 for full scale voltage output, send in **ALMH 0500** command. To set up 100%Vol, send in **ALMH 9999**.

6.3 C (U_{AnOut}) and $U_{AnOut}(C)$ conversion.

MODE	C (U_{AnOut})	$U_{AnOut}(C)$
DACMODE1:	$C = \frac{ALMH * (U_{AnOut} - 0{,}4)}{160}$	$U_{AnOut} = 0{,}4 + 160 * \frac{C}{ALMH}$
DACMODE2:	$C = \frac{ALMH}{50} * \left(\frac{U_{AnOut}}{U_{sup}} - 0.5 \right)$	$U_{AnOut} = U_{sup} * (50 * \frac{C}{ALMH} + 0{,}5)$
DACMODE3:	$C = \frac{ALMH}{50} * \left(0.5 - \frac{U_{AnOut}}{U_{sup}} \right)$	$U_{AnOut} = U_{sup} * (0{,}5 - 50 * \frac{C}{ALMH})$

Where:

C is gas concentration, in %Vol,

U_{AnOut} is output voltage in V,

U_{sup} is sensor power supply voltage in V.

ALMH – concentration for upper voltage level, in %Vol*100.

See illustrations on **Fig. 3**, **Fig. 4** and **Fig. 5**.

EXAMPLE:

Aim: Need to have AnOut with range 1.5-2.0 V for 0-5%Vol CH4 , Usup= 3.0V.

Solution:

1. Send **DACMODE2** and check that response is “Ok”.
2. Calculate **ALMH** coefficient:

$$ALMH = \frac{50 * C_{MAX}}{U_{C_{MAX}} / U_{\sup} - 0{,}5}$$

$$ALMH == \frac{50 * 5[\%Vol]}{2.0[V] / 3.0[V] - 0.5} = \frac{250}{0.16667} = 1500$$

3. Send **ALMH 1500** and check that response is “Ok”.
4. U_{AnOut} *to* ***C*** conversion is:

$$C = \frac{1500}{50}\left(\frac{U_{AnOut}}{3.0} - 0.5\right) = 10 * (U_{AnOut} - 1.5)$$

7. STORAGE AND TRANSPORTATION

The transportation of the sensors should be performed by all means of transportation in covered transportation vehicles as well as in the heated pressurized plane compartments in accordance with the rules of cargoes transportation effective for the respective type of transportation.

The sensors in the Manufacturer's package should be kept in the Supplier's and Customer's storages under storage conditions pointed in Table 1. The atmosphere of storage premises should be free from harmful admixtures provoking corrosion.

8. WARRANTY

The Manufacturer guarantees compliance of the sensors with specifications and requirements stated in this UM if Customer meets conditions of operation, transportation and storage.

During the warranty period, Manufacturer has the right to replace or repair all the products that, according to his unquestionable judgement, are found to be defective, if defect is due to a fault of Manufacturer.

The warranty period is 24 months since the date of sensor shipment to a Customer. The date of shipment is registered in the ESAT.413347.006 PS datasheet.

Manufacturer is not responsible for the sensors failure and discontinue in case of:

- violations of conditions of operation, transportation and storage stated in UM;
- sensor has marks of unauthorized repair;
- mechanical damages, appeared after handover the sensors to Customer, effect of temperature and pressure beyond conditions, chemical erosion, ingress of foreign substances inside the body of the sensor;
- defects due to electrical interface unspecified by UM and other documentation conveyed to the Customer;
- defects due to force majeure circumstances, disastrous occurrences, intended or reckless act of Customer or third party;
- defect or failure due to installing, damaging, changing or erasing of sensors firmware or changing sensors settings because of misuse of service codes via UART.
- defect or failure due to using power or signal cables unspecified by technical regulations and standards or operating the sensor with EMC influences exceeds maximums specified in IEC 61000-4-3.

Replacement or repair of defective sensor does not lead to setting a new warranty period.

The Manufacturer is not responsible for possible damages, direct or indirect inflicted to people or properties if this is happened in case of repair, storage and transportation rules violation or due to purport or reckless act of Customer or third party. The Manufacturer does not respond as well for possible damages, direct or indirect inflict to appropriate equipment as the result of change, damage or data loss.

The warranty repair or replacement is effecting in site of Manufacturer or designated representative.

Shipping and packaging charges and any other incidental expenses for the products returned to Manufacturer will be at the Customer’s own risk and charged to him.

9. CONTACTS

MIPEX Technology /Optosense LLC

27, AD, Engelsa prospect, St. Petersburg, 194156, Russia,

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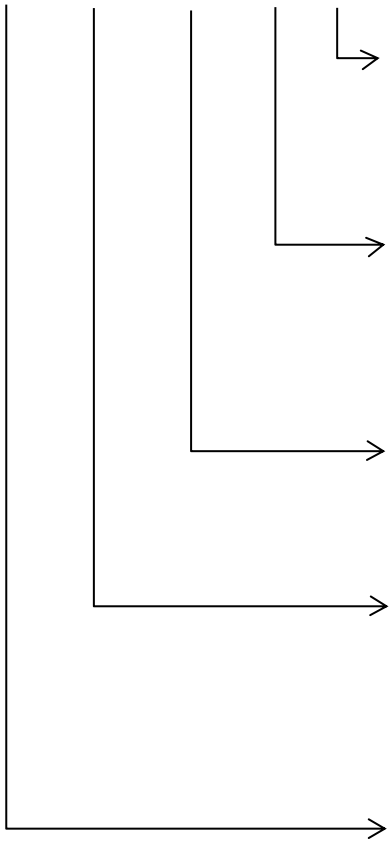
web: http://www.mipex-tech.com

e-mail: info@mipex-tech.com

support: support@mipex-tech.com

Appendix A. Sensor types and characteristics.

MIPEX-03-B-RX-C.D



Output format:

1. - analog, 3 pins, pellistors replacement
2. - digital and analog, 5 pins;
3. - digital, 4 pins.

Construction:

1. - stainless steel, “Standard”;
2. - stainless steel, with side holes, “Fast response”;
3. – plastic.

Application:

R – calibration gas and range
X - temperature class and accuracy
(see **Table 5** for details).

Target gas:

1. - CH4, methane;
2. - C3H8, (CnHm, hydrocarbons);
3. - CO2, carbon dioxide;
4. - CH4/CH4 +C2H6 acc. to IEC 60079-29-1

MIPEX model number

Table 2. MIPEX-03-X-XX-1.X types, interfaces and overall dimensions (stainless steel).

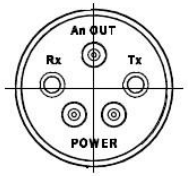
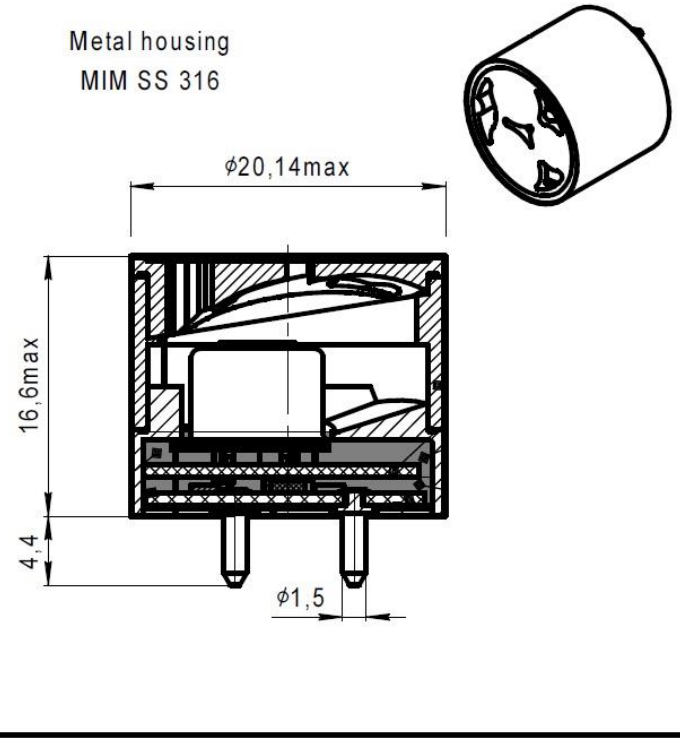
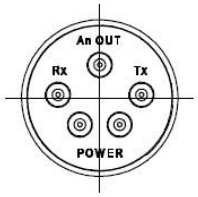
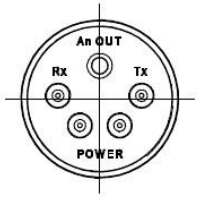
Part number	Sensor type	Gas	Weight,g	Interface	Housing type
ESAT.413347.006	MIPEX-03-1-XX-1.1	CH_4	16,35		
-01	2-XX-1.1	C_3H_8	16,35		
-02	3-XX-1.1	CO_2	16,35		
-03	4-XX-1.1	$CH_4/CH_4+C_2H_6$	16,35		
-04	1-XX-1.2	CH_4	16,6		
-05	2-XX-1.2	C_3H_8	16,6		
-06	3-XX-1.2	CO_2	16,6		
-07	4-XX-1.2	$CH_4/CH_4+C_2H_6$	16,6		
-08	1-XX-1.3	CH_4	16,48		
-09	2-XX-1.3	C_3H_8	16,48		
-10	3-XX-1.3	CO_2	16,48		
-11	4-XX-1.3	$CH_4/CH_4+C_2H_6$	16,48		

Table 3. MIPEX-03-X-XX-2.X types, interfaces and overall dimensions (stainless steel with side holes).

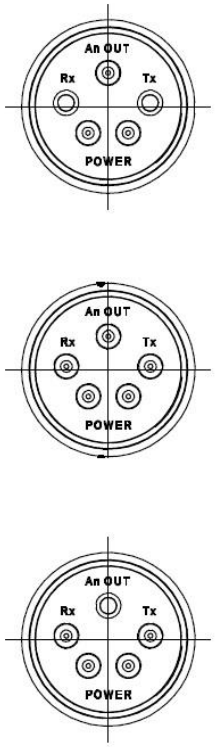
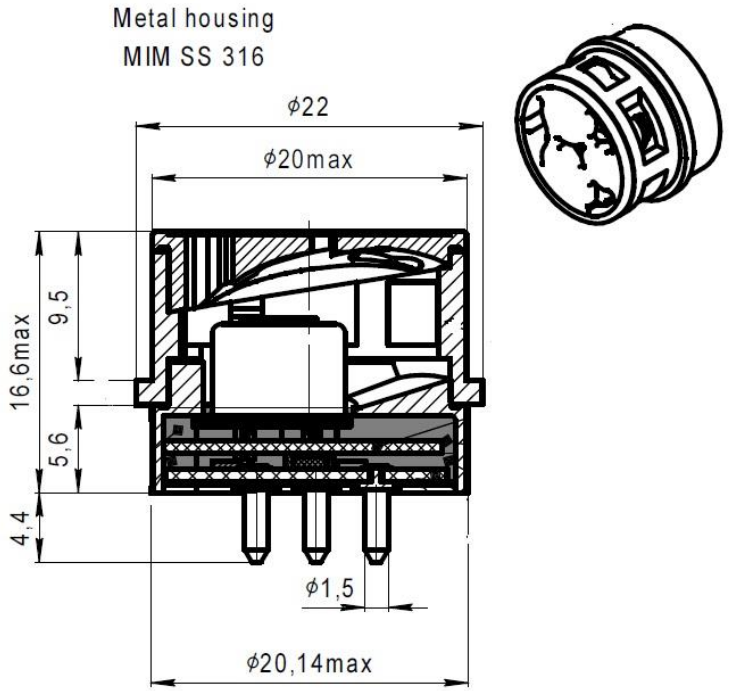
Part number	Sensor type	Gas	Weight,g	Interface	Housing type
-12	1-XX-2.1	CH_4	15,9		
-13	2-XX-2.1	C_3H_8	15,9		
-14	3-XX-2.1	CO_2	15,9		
-15	4-XX-2.1	$CH_4/CH_4+C_2H_6$	15,9		
-16	1-XX-2.2	CH_4	16,3		
-17	2-XX-2.2	C_3H_8	16,3		
-18	3-XX-2.2	CO_2	16,3		
-19	4-XX-2.2	$CH_4/CH_4+C_2H_6$	16,3		
-20	1-XX-2.3	CH_4	16,0		
-21	2-XX-2.3	C_3H_8	16,0		
-22	3-XX-2.3	CO_2	16,0		
-23	4-XX-2.3	$CH_4/CH_4+C_2H_6$	16,0		

Table 4. MIPEX-03-X-XX-3.X types, interfaces and overall dimensions (plastic).

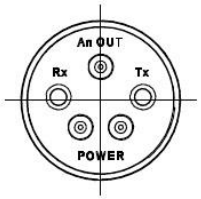
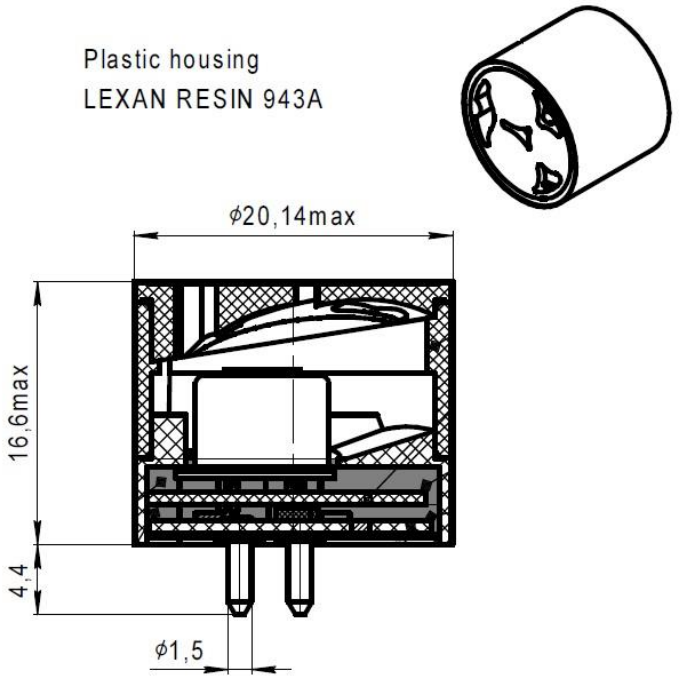
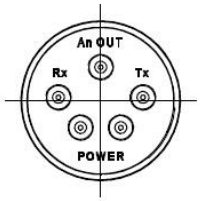
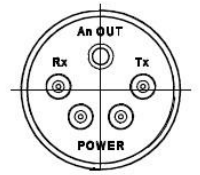
Part number	Sensor type	Gas	Weight,g	Interface	Housing type
-24	1-XX-3.1	CH_4	6,0		
-25	2-XX-3.1	C_3H_8	6,0		
-26	3-XX-3.1	CO_2	6,0		
-27	4-XX-3.1	$CH_4/CH_4+C_2H_6$	6,0		
-28	1-XX-3.2	CH_4	6,4		
-29	2-XX-3.2	C_3H_8	6,4		
-30	3-XX-3.2	CO_2	6,4		
-31	4-XX-3.2	$CH_4/CH_4+C_2H_6$	6,4		
-32	1-XX-3.3	CH_4	6,14		
-33	2-XX-3.3	C_3H_8	6,14		
-34	3-XX-3.3	CO_2	6,14		
-35	4-XX-3.3	$CH_4/CH_4+C_2H_6$	6,14		

Table 5. Individual specifications by type of MIPEX-03.

<table>
<tr><th>Calibration gas</th><th>Measurement range **</th><th>RX code (marking)</th><th>Accuracy</th><th>Additional temperature error</th><th>Additional pressure error</th><th>Additional humidity error</th><th>Temperature range</th><th>Operation temperature</th></tr>
<tr><td rowspan="3">CH4</td><td>50LEL (0-2.5% Vol - alarm sensor)</td><td>00</td><td rowspan="7">±0,1 % Vol. or ±5 % of indication, whichever value is greater</td><td rowspan="3">±0,2% Vol. or ±10% of indication from 20°C, whichever value is greater (test: –10°C, 20°C, 40°C).</td><td rowspan="7">±0,2% Vol. or ±30% of indication from 100kPa (test: 80kPa, 100kPa, 120kPa)</td><td rowspan="7">±0,2 % Vol. or ±15 % of indication from the indication at adjustment at 40 °C (test: 20 %RH, 50 %RH,90 %RH)</td><td rowspan="3">-10… +40 (for portable devices, according to EN 60079-29-1)</td><td rowspan="10">-40… +60</td></tr>
<tr><td>5% (0-5 Vol.% – measure, 5-100% Vol – indication;)</td><td>10</td></tr>
<tr><td>100% (0-100 % Vol – measure;)</td><td>20</td></tr>
<tr><td>CO2</td><td>1,5% (0-1.5 % Vol – measure, 1.5-2.5% Vol – indication)</td><td>30</td></tr>
<tr><td rowspan="3">CH4</td><td>50LEL (0-2.5% Vol - alarm sensor)</td><td>01</td><td rowspan="2">±0,2% Vol or ±10% of indication from 20°C, whichever value is greater, in temperature range from –10°C to 40°C (test: –10°C, 20°C, 40°C ±0,4% Vol or ±20% of indication from 20°C, in temperature ranges from -40°C to -10°C and from 40°C to 60°C, whichever value is greater, (test: –25°C, 20°C, 55°C) whichever value is greater, (test: –25°C, 20°C, 55°C).</td><td rowspan="4">-40… +60 (for fixed devices, according to EN 60079-29-1)</td></tr>
<tr><td>5% (0-5 Vol.% – measure, 5-100% Vol – indication;)</td><td>11</td></tr>
<tr><td>100% (0-100 % Vol – measure;)</td><td>21</td><td rowspan="2">±0,2 % Vol or ±10 % of indication from 20°C, whichever value is greater, in temperature range from –10°C to 40°C (test: –10 °C, 20 °C, 40 °C, unspecified performance in temperature ranges from -40 °C to -10 °C and from 40°C to 60°C.</td></tr>
<tr><td>CO2</td><td>1,5% (0-1.5 % Vol – measure, 1.5-2.5% Vol – indication)</td><td>31</td></tr>
<tr><td rowspan="3">C3H8</td><td>0-100 % LEL – measure</td><td>61</td><td rowspan="3">±3% LEL or ±5% of indication, whichever value is greater</td><td rowspan="3">±5 % LEL or ±10 % of indication from 20 °C, whichever value is greater, in temperature range from –10°C to 40°C (test: –10 °C, 20 °C, 40 °C) ±10 % LEL or ±20 % of indication from 20 °C, in temperature ranges from -40°C to -10°C and from 40 °C to 60 °C (test: –25 °C, 20°C, 55°C).</td><td rowspan="3">±5% LEL or 30% of indication from 100kPa (test: 80kPa, 100kPa, 120kPa)</td><td rowspan="3">±5 % LEL or ±15 % of indication from the indication at adjustment at 40°C (test: 20%RH, 50 %RH, 90 %RH</td></tr>
<tr><td>0- 50% LEL – alarm sensor</td><td>71</td></tr>
<tr><td>10% Vol</td><td>81</td></tr>
</table>

Appendix B. Connection diagram.

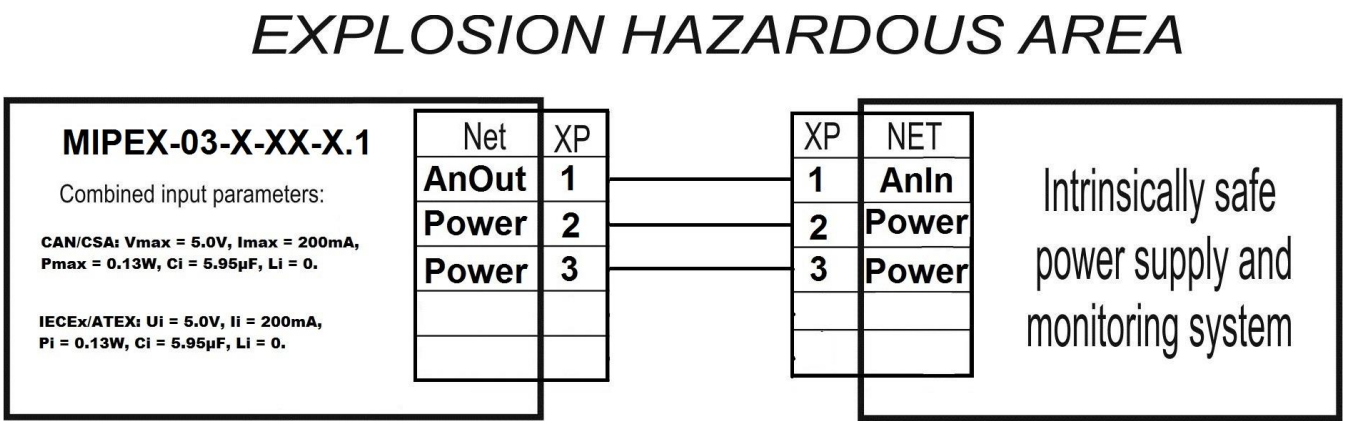


Fig. 6. Connection diagram for MIPEX-03-X-XX-X.1

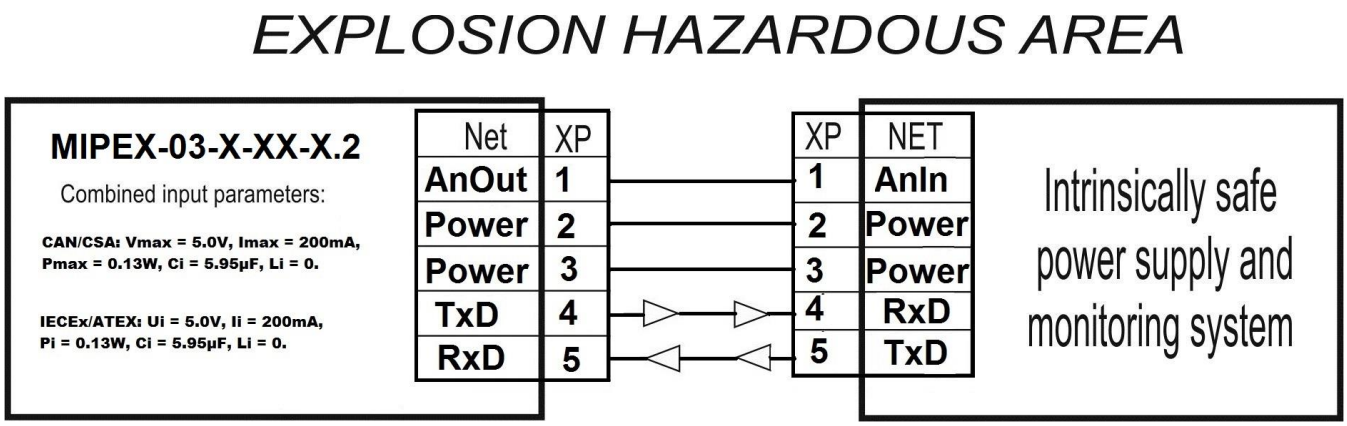


Fig. 7. Connection diagram for MIPEX-03-X-XX-X.2

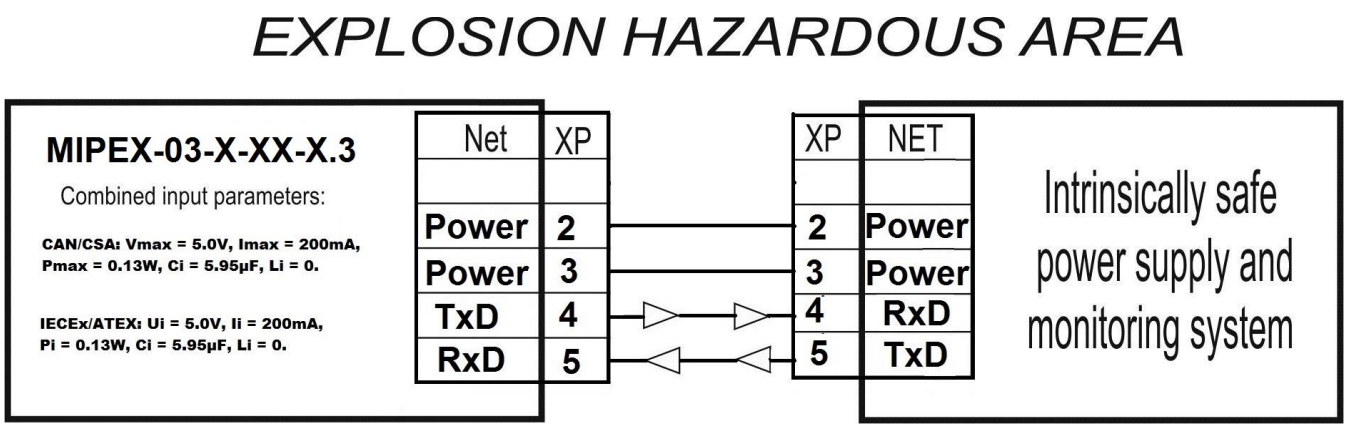


Fig. 8. Connection diagram for MIPEX-03-X-XX-X.3

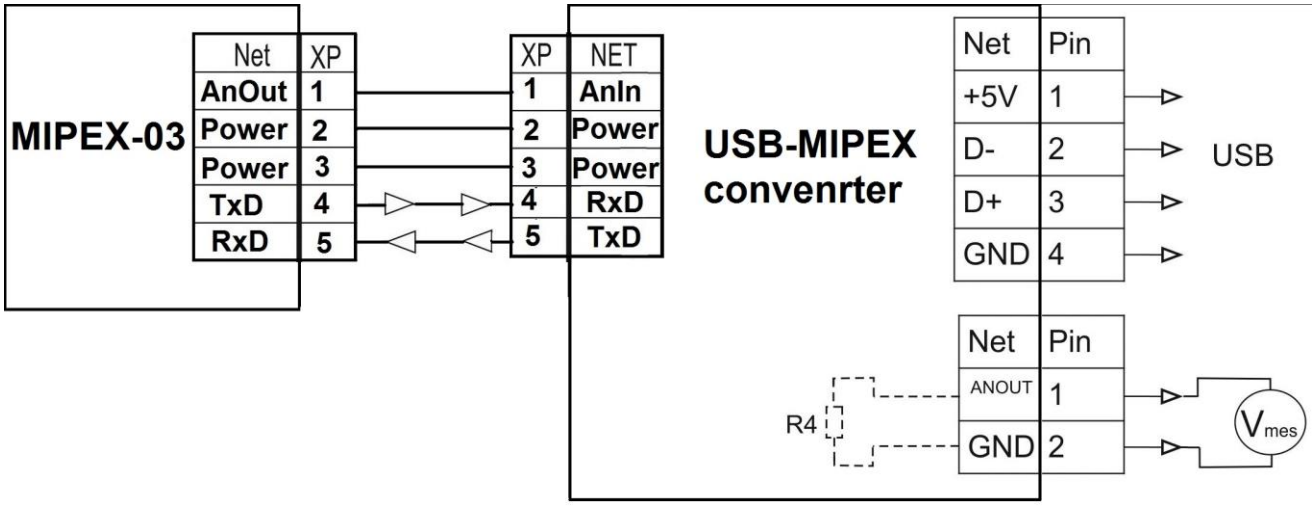


Fig. 9 Connection diagram for MIPEX-03 with USB-MIPEX converter during testing.

Appendix C. UART communication protocol.

Firmware release 25.6

Always check the command syntax before sending. The commands, other than specified in current user manual are not allowed. Otherwise it might bring to malfunction of the sensor.

In earlier firmware versions some commands/modes are not available.

1. General information

- MIPEX-03 communication protocol provides data exchange based on “Request-Response” principle.
- Transducer has fix 9600 baud rate
- Electrical parameters of UART-transceiver are pointed in 5.2.3.

Data format: 8-bit message, 1 stop bit, no parity.
Frame format (if other is not specified):

- the symbols of commands are ASCII coded,
- carriage return (CR) symbol must be after each command,
- all symbols in command must be sent in one word. Delay between symbols are not more than 40 ms.

The words of the response are separated with a tabulation symbol (09h) or space symbol (20h) (specified below for every command). For some commands request is not intended to answer according to following protocol. Sensor returns confirmation or rejection of command. Request on correct command with correct data returns command name with **OK** separated by (09h) or (20h). Request on correct command with wrong data returns command name with **FAULT** separated by (09h) or (20h). There is no reaction on wrong command.

2. Data request command

There are several types of commands for analyzing sensor mode or request factory settings or sensor properties**.**

2.1 Operating commands for the sensor:

The command @ is 16-bit concentration data. The lead byte **Conc1H** transmitted first, low byte **Conc1L** at the end of response.

The command @***X** is initiate regular transmitting of gas concentration data to UART. Here **X** - is a value in range 0…9 (ASCII) proportion to standard operating period of the sensor (1.28 sec). Structure of @ and @***X** commands are shown in the Table 6.

F command returns the detailed information about working condition of the sensor. Response on **F** command is 5 byte in ASCII separated by (09h). Structure of **F** command response is shown in Table 7.

Table 6. Structure of @ and @*X commands

Command @ (40h 0Dh) response, byte number and data		**Command @*x (40 2A x 0D) response, byte number and data**		
1	2	1	2	3
Conc1H	Conc1L	@(40h)	Conc1H	Conc1L

Table 7. Structure of F command response

Command F (46 0D) response		
Byte number	**Byte data**	**Data description**
1	0Eh	Special character
2-6	Termo	Sensor temperature in ADC readings
7	09h	Tabulation
8-12	<Stz>	Ratio Us/Uref with temperature index
13	09h	Tabulation
14-18	Us	Operating signal in ADC readings
19	09h	Tabulation
20-24	Uref	Reference signal in ADC readings
25	09h	Tabulation
26-30	Stz0	Ratio <Stz> with manual zeroing settings (ZERO)
31	09h	Tabulation
32-36	Stz	Ratio Stz0 with drift compensation algorithm
37	09h	Tabulation
38-42	Stzkt	Ratio Stz with coefficient of temperature sensitivity
43	09h	Tabulation
44-48	Conc	Concentration (according to a factory calibration)
49	09h	Tabulation
50-54	Conc1	Concentration scaled by user
55	09h	Tabulation
56-60	Status	Status word (see Table 8)
61	09h	Tabulation
62-71	Sn	Sensor serial number
70	09h	Tabulation
71	ControlSum	Checksum based on XOR
72	09h	Tabulation
73	0Dh	Carriage return

Table 8. Status word description

Status word	Description
00	Normal mode, static temperature
10	Warm-up
11	Sensor rate more than 1 Hz
20	Non-statically temperature operating mode (from 0.15 to 0.6 grad/min);
21	Dynamical temperature operating mode (more than 0.6 grad/min, no compensation)
22	Temperature is changed faster than 2 grad/min
30	Values of **Signal** or **Ref** are lower than tolerance
31	Signals ratio (Stz0) is exceed upper limit
40	Out of operation temperature range
50	Abrupt change of signal or high noise level
51	Complex status (contact support for details)
90	Firmware corruption

2.2 Request commands of factory settings and properties:

SREV? – request the firmware version. For example, send **SREV? -** answer MIPEX-3_25.6.

SRAL? – request the sensor serial number (SN). The answer is ASCII 8 byte and 0Dh symbol.

RT? – request of sensor type. The answer is ASCII 5-byte and 0Dh symbol (the codes listing is available upon request).

RX? – checking the sensor's characteristics (temperature class, calibration rage and accuracy). The answer is ASCII 2-byte and 0Dh symbol. See Table 5 for details.

ID? – request of ID. The answer on this command returns the summary info about sensor type, serial number, characteristics and firmware version (ASCII). For example:

```
ID?                                  <-Request
02019 08035278 02 MIPEX-2_25.6       -> Response
```

3. Sensor setting and calibration commands

The following commands are used for sensor calibration and settings.

ZERO2 – setting zero in whole operating temperature range. The command initiate calculation and store a unifying zero coefficient to the memory. In case of supplying this command, concentration **Conc** = 0, **Conc1** = 0, relation **Stz** is corrected to 10000 (see Table 7).

CALB AAAA – span gas calibration command. **AAAA** is Control Gas Mixture (CGM) concentration value in %Vol.*100. For example, **AAAA**=0198 corresponds to 1.98 %Vol. See Appendix D for detailed procedure. Applying the command be sure that following conditions are met:

- Entered value must not be different from current readings more than 20 times with regard to all units converted to %Vol.

- CGM concentration must be more than 0,2% Vol.
- If these conditions are not accomplished, sensor responds **CALB AAAA FAULT**.

INIT – return to a factory calibration settings.

CALB1 XXXXX – writing scale coefficient for concentration **Conc1**. The command might be used to re-calibrate the sensor if the scale coefficient is known. Here **XXXXX** – value of scale coefficient normalized to 10000 (for example: to initiate scale coefficient 0.7 send **CALB1 07000)**. The scale coefficients for different gases are individual for each sensor. To achieve cross-coefficients contact Optosense LLC.

From the firmware ver.2x.6 introduced new autozeroing algorithm and the possibility to adjust the temperature coefficients by user.

Autozeroing is embedded in self-diagnostics algorithm of the sensor. It starts after sensor is powered up. Self-diagnostics is operating during the sensor is on. If anyway, zero shift is observed, manual zeroing procedure is recommended. Use the following command to control the algorithm:

AZERO ON – turn on autozeroing algorithm.

AZERO OFF - turn off autozeroing algorithm.

AZERO? – check current autozeroing status. Response is **AZERO ON** or **AZERO OFF**.

The sensor is able to adjust the temperature coefficients and store it in the controller memory. There are up to 8 correction values (pair of data: temperature and signal ratio **<Stz>**) could be written automatically or in manual mode. Temperature range from -40 to +60ºC is divided to equal intervals about 12.5ºC. Each interval is used for responsible operating temperature.

Automatic mode procedure:

- Place the sensor in the chamber with nitrogen and send **ZERO0** command. This command is erase factory temperature coefficients and write the same data for all memory cells.
- Change the temperature in range -40 to +60^{0}C with about 12.5^{0}C interval. Stay the sensor in each temperature interval for some minutes to fix temperature fluctuation into the sensor. Write data by **ZERO** command for the current temperature interval and signal ratio **<Stz>**.
- Repeat **ZERO** command for all temperature intervals (see **Fig. 10**).

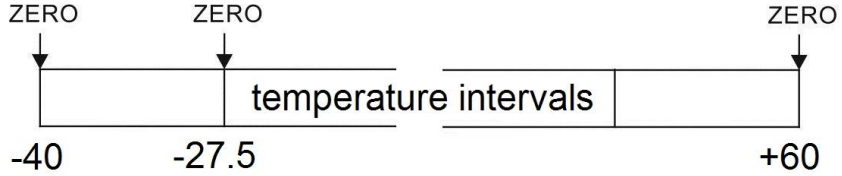


Fig. 10. Scheme of setting temperature coefficients in automatic mode.

Manual mode procedure:

It is possible to calculate temperature coefficients if the user fined the most preferred temperature data and signal ratio **<Stz>**.

Use **ZERO XXXXX YYYYY** command to set user data. Here **XXXXX** – temperature data, **YYYYY** – signal ratio **<Stz>**. Data in the table are arranged automatically. The new data is rewrite previous coefficients.

Appendix D. Sensor zeroing and calibration.

1. Calibration is available using UART only.
2. Closing gas-sampling holes of the sensor impairs response time.
3. To achieve correct data during the tests, be sure there are no:
   - excessive force on sensor housing,
   - 100% humidity (dewpoint),
   - out of specified range of environmental pressure,
   - fast temperature change (more than 0.6 ºC/min), dust (if dust filter isn't used),
   - sensor rate no more than 1Hz.

The setting of zero and calibration of the sensor is performed in the course of the primary installation into a gas analyzer as well as annually during preparation to conducting a check. In any cases the setting zero should be done before calibration.

The devices given in Fig. 11 and the CGM are used in the course of conducting operations.

The operations on setting zero and calibration of the sensor shall be carried out by a qualified specialist outside of the explosion-hazardous zone at normal conditions in the following sequence:

a) The sensor shall be connected in accordance with Fig. 11. Converter USB should be connected to the sensor and PC.

b) Setting to zero use the following method. In 5 min after power supply the pure nitrogen N2 CGM No.1 (depends on used calibration gas see the Table 9, Table 10 or Table 11) is connected, in 1 min after CGM supply a command **ZERO2** of zero setting is supplied, the sensor readings should get set to zero with respect to digital interface in accordance with Appendix C.

   Additionally it is possible to set zero during the warm-up period. Switch ON/OFF the sensor two times during the first minute. Sensor will starts zeroing algorithm automatically after the third switch ON.

c) The CGM No.2 is connected, in 1 min after CGM supply a **CALB AAAA** command is given, where **AAAA** is a value of CGM concentration (e.g. 1.98% vol. – 0198). After that the value Conc1 – (scaled concentration) should get established equal to a value assigned according to command **CALB AAAA**. The scale coefficient shall be stored in the module memory up to the next calibration.

d) The CGM No.3 is connected and the sensor readings are checked via digital serial RS-232.

If the requirements to the sensor error are not fulfilled in accordance with Table 5, the procedure of setting zero and calibration shall be repeated. In case of a repeated non-compliance of the sensor readings to the value of concentration of CGM No.3, the sensor is subject to replacement and dispatching to the Manufacturer for repair.

For MIPEX-03 with analog output see chapter 6.

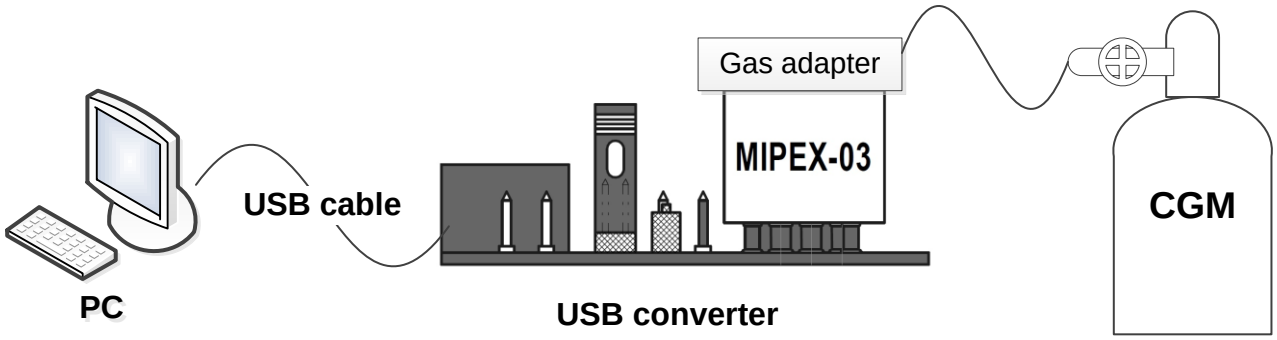


Fig. 11 Typical scheme of MIPEX-03 calibration

List of CGM used for checking IR gas sensors MIPEX-03

The recalculation to % of LEL shall be effected in accordance with the following formula for concentration expressed in volume fraction, vol. %:

$$LFSCL = \frac{100 \times C}{C(h)};\%$$

where
LFSCL is % LEL
C – component content in volume fraction, vol. %;
C(h) – LEL of component, % (constant);
C(h) = 4.4 % – for methane;
C(h) = 1.7 % – for propane.

Table 9. CGM used for CH4 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$CH_4 – N_2$	2,2 (50)	±0,25	±0,04	3883-87
3	$CH_4 – N_2$	4,15 (94)	±0,25	±0,04	3883-87
4	$CH_4 – N_2$	40	±2,5	±0,4	3892-87

Table 10. CGM used for C3H8 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$C_3H_8 – N_2$	0,85 (50)	±0,05	±0,015	5328-90
3	$C_3H_8 – N_2$	1,6 (94)	±0,1	±0,05	EM 06.01.648
4	$C_3H_8 – N_2$	3,40 (200)	±1,00	±0,5	

Table 11. CGM used for CO2 calibration gas.

CGM Nos according to text	Component composition	Composition of measured component, vol. %, (% of LEL)	Permissible deviation limits, vol. %	Limits of permissible error of qualification, vol. %	Number as per State Register or Standard designation
1	N_2	100	-	-	GOST 9392-74
2	$CO_2 – N_2$	1	±0,05	±0,015	
3	$CO_2 – N_2$	2.5	±0,1	±0,05	

Appendix E. Attaching the dust filter.

Tools required - tweezers, cloths.

Time required – 2… 3 min.

- Perform this work in a well illuminated and well ventilated room.
- After attaching the dust filter, perform the procedure of the sensor zeroing (for details, see Appendix D for details).

To attach the dust filter, perform the following steps:

- Wipe the sensor top surface with a cloth that is dampened with absolute alcohol. For the MIPEX-03-X-XX-2.X sensors, perform the same operation on the side surface.
- Retrieve the teflon tape-bonded dust filters from packing.
- Detach a filter from the teflon tape with tweezers.
- Align the filter to the top surface center with tweezers, and then press on it. For the MIPEX-03-X-XX-2.X sensors, perform the same operation on the side surface.

After the dust filter was attached, zeroing procedure must be performed (see Appendix D for details).